THE BACTERIA OF THE INTESTINAL TRACT OF MAN[1]

IT has been stated that the average healthy adult on a normal mixed diet excretes daily in the feces a number of bacteria, which have been variously estimated from 128 billion to 33 trillion. This truly enormous number of bacteria would weigh approximately 5.5 grams when dried, and the nitrogen in this dried mass would be about 0.6 gram, corresponding to from 46 to 50 per cent. of the total fecal nitrogen. It is very certain that this number of bacteria is not taken in the food, and, furthermore, the fecal organisms are not necessarily the same as those found in the food. Hence the conclusion is reached that there must be a very great daily proliferation of bacteria in the intestinal tract, and in this sense the intestinal tract is the most efficient and active combined culture medium and incubator with which science is familiar.

The question naturally presents itself, why is there such a tremendous growth of bacteria daily, and why is it that the bacteria taken in with the food are not those which appear in the fecal contents? A rapid survey of the life history of the intestinal bacteria will explain at least some of the facts. At birth the intestinal content, the meconium, is sterile. This would be expected, because the uterine cavity is sterile. Very shortly after birth bacteria make their appearance in the mouth of the new-born, and organisms appear in the meconium from four to twenty hours post partum, depending upon environmental conditions. This initial infection of the meconium is a mixed one. Various adventitious organisms, even pathogenic bacteria, may appear in it. This is a period of mixed infection, and the number of organisms in the meconium increases rapidly after the first food enters the intestinal tract. After two to three days post partum, when the intestinal tract has become thoroughly permeated with milk, the organisms observed in the feces—for the meconium has largely disappeared by this time—begin to assume a monotony of form and a regularity of type, which contrasts sharply with the preceding period of mixed infection. This is a transitional period during which the permanent characteristic nursling bacteria appear and soon become dominant.

The types of bacteria which constitute the normal fecal flora of the nursling are few in number and definite in their chemical characters. The most prominent of these, *B. bifidus,* so-called because of its developmental peculiarities in artificial media, is a strict anaerobe. Other organisms, the so-called Kopfchen bacillus, *B. coli, B. lactis aerogenes* and *Micrococcus ovalis,* are, as a rule, very much fewer in numbers than *B. bifidus,* and, under normal conditions, apparently less important. The question arises, why should an obligate anaerobe, as *B. bifidus,* dominate the nursling's intestinal flora? It must be remembered that breast milk, which is the normal diet of the nursling, consists monotonously of about 7 per cent. of lactose, about 3 per cent. of fat, and but 1.5 per cent. of protein. Consequently, the intestinal tract of the infant under ordinary conditions is practically continuously bathed in a nutrient medium containing at all times at least a minimal amount of sugar. The normal infantile feces is always slightly acid in reaction, and this acid is lactic acid chiefly. It is a significant fact that the dominating organism, *B. bifidus,* is a lactic acid-producing microbe. It is also a significant fact that the reaction of the normal nursling feces is acid enough to inhibit the growth of practically all putrefactive bacteria; there are few or no putrefactive bac-

[1] From the Bacteriological Laboratory of the Northwestern University Medical School.

teria in the normal infantile feces. There appears to be a definite relationship between the high percentage of lactose, the dominance of an obligately lactic acid-fermenting organism, and the absence of putrefactive bacteria in the normal infantile intestinal flora. This infantile flora, furthermore, appears to be a protective one in the sense that it inhibits the growth of bacteria which might produce either putrefaction or disease. These latter organisms are somewhat intolerant of lactic acid. It may be remarked parenthetically that one of the first indications of intestinal disturbance in infants is the temporary or even permanent disappearance of this lactic-acid flora.

B. bifidus is an organism which does not thrive in artificial media in the absence of sugars, and it is not surprising to find, therefore, that as the breast-fed infant becomes older and its dietary demands more varied, *B. bifidus* tends to disappear from the fecal mass. In the case of bottle-fed babies, this disappearance practically coincides with the substitution of cow's milk for human milk. Cow's milk contains relatively less sugar and more protein than human milk. In either instance, the decrease of *B. bifidus* appears to follow very closely, under normal conditions, the change in diet which results in a diminished amount of carbohydrate in proportion to the nitrogenous substance. That is to say, as the proportion of protein increases and the proportion of carbohydrate decreases in the diet, *B. bifidus* also tends to decrease. The decrease in the typical nursling organisms is accompanied by an increase in the numbers of *B. coli* which then dominate the intestinal tract and form about 80 per cent., roughly, of the total living fecal organisms of adolescence, and which persist in this proportion in normal individuals until death.

B. coli differs from *B. bifidus* in one noteworthy respect. *B. bifidus,* as has been pointed out before, is a strictly, almost obligately, fermentative organism: it does not grow in the absence of sugars. *B. coli* is far more plastic in this respect: it can grow equally well in media containing protein and utilizable carbohydrate, or in media from which utilizable carbohydrates are excluded. It can accommodate its metabolism to the varying foods presented to it in the intestinal contents. This plasticity of the colon bacillus and its ability to develop in the average intestinal contents, explains in a satisfactory manner the dominance of this organism throughout life.

Turning now to the distribution of bacteria in the intestinal tract of the normal adults, it is found that the stomach contents are practically sterile under normal conditions. The usual explanation for this sterility is the acidity of the gastric contents, and while this explanation may not be wholly satisfactory, it suffices for the moment. When the hydrochloric acid acidity of the stomach contents becomes diminished through disease, it is found that the numbers of bacteria in the stomach contents may increase greatly. The duodenum also during those periods when it is empty is practically sterile. The bacterial population increases as duodenal digestion increases, and diminishes as the duodenal contents are passed on to the lower levels.

The greatest number of bacteria, living bacteria, that is, is found in the region of the ileocecal valve and the ascending branch of the colon. Here the contents stagnate, as it were, and they eventually become so desiccated through the withdrawal of water that bacterial life is retarded. From the ascending colon progressively to the end of the intestinal tract the number of living bacteria under ordi-

nary conditions appears to diminish, although there are even in the fecal contents great numbers of living organisms.

The significance of the intestinal flora has been variously interpreted. Various theories have been proposed to explain their relation to the well-being of man. The theory which has received the greatest attention is that one which assumes that the normal intestinal bacteria assist the digestion of food for the host through the elaboration of certain ferments, and also that these organisms are under normal conditions in a sense a protection to the host in that their activities are in opposition to those of adventitious pathogenic bacteria, which might otherwise gain a foothold in the intestinal tract and become invasive. A certain amount of theoretical evidence was originally brought forth in support of the digestive action of the intestinal bacteria: it was assumed that in the herbivora certain cellulose-dissolving bacteria were very active and that the activities of these bacteria made assimilable the otherwise resistant cellulose.

Certain observers have attempted to approach the problem of the significance of the intestinal bacteria from another point of view. Nuttall and Thierfelder delivered guinea-pigs by Cæsarean section and attempted to raise them in a sterile environment on sterile food. For two weeks these sterile guinea-pigs increased in weight and appeared to be reasonably healthy. These observers drew the conclusion that the intestinal bacteria were not necessary for the well-being of these guinea-pigs at least. These experiments were not accepted by Schottelius as being conclusive. He claimed that the experiments were not carried on long enough. Schottelius experimented with chicks hatched from sterile eggs. Parenthetically, it should be remarked that Schottelius had the greatest difficulty in finding sterile eggs to start with. However, after considerable investigation he succeeded in getting a considerable number of sterile eggs which he divided into three groups. These were incubated under sterile conditions, and the chicks developing from one group were kept in an absolutely sterile environment and fed on sterile food; a second group were kept under the same conditions for ten days and then fed with infected food; the third group were controls and were kept under ordinary conditions. The first group, the sterile chicks, did well for ten days, but after that time their development was seriously retarded. The second group also did well for ten days, and then, as the first group began to exhibit signs of abnormalities, they were placed on infected food: they gained rapidly. The third group, kept under ordinary conditions, did well from the start. Schottelius believed that his experiments showed that the intestinal bacteria were necessary for the development and well-being of chicks.

Madame Metschnikoff made similar observations on tadpoles, and Moro performed the same experiments with turtles. These observers agree with Schottelius that the intestinal flora appear to be necessary for the well-being of the animals they experimented on.

A line of evidence which is somewhat different from this was brought forward by Levin. He examined the fecal contents of many Arctic mammals in the Arctic regions, and he found few or no bacteria in them. He believed that an intestinal flora was unnecessary for the development of these animals. It should be remarked parenthetically, however, that Arctic mammals brought to the temperate regions rapidly acquire an intestinal bacterial flora, and these organisms do not seem to interfere with the well-being of their host.

The net result of these experiments would suggest that man has a bacterial population in his intestinal tract; that under normal conditions the organisms in the intestinal tract are fairly characteristic and constant; normally they are harmless; they may be protective; and that up to the present time it is practically impossible to get rid of them.

Attempts have been made to sterilize the intestinal contents, either by administering sterile food or by the use of antiseptics. Sterile food appears to reduce somewhat the numbers of intestinal bacteria, but the reduction is not great, and this line of experimentation has not been successful. Many different kinds of antiseptics have also been tried, and while various results have been claimed, the net result appears to be that the temporary reduction in numbers, which is frequently observed, is largely referable to increased peristalsis and quick removal of the intestinal contents. It has become apparent from these observations that the strength of antiseptics necessary to sterilize the intestinal contents would be sufficient to kill the host long before the bacteria were eliminated.

The intestinal bacteria may become a menace to the health of the host. Occasionally, adventitious bacteria, as the typhoid, dysentery, cholera, or paratyphoid organisms, much less commonly the tubercle bacillus, may gain lodgment in the intestinal tract, increase greatly in numbers, invade the tissues of the host, and, if care is not taken to sterilize the feces, produce progressive disease from host and host. From the individual point of view the intestinal flora under ordinary conditions are innocuous, and perhaps even to a moderate degree protective. Under abnormal conditions, when progressively pathogenic bacteria gain a foothold in the intestinal tract, the intestinal flora may become a menace to health and even to life. The significance of the intestinal contents to man in general is perfectly obvious. The tremendous numbers of bacteria which can be excreted daily, particularly if they happen to be disease-producing, as typhoid, may become a matter of real concern to the health of communities, for the disposal of feces in a manner to render them innocuous is not a particularly simple matter. Once the intestinal bacteria have escaped into water supplies, or have gained access to foods, the progressive damage which may be brought about may be very great.

A. I. KENDALL
NORTHWESTERN UNIVERSITY

PROTECTION OF BIRDS IN THE MALAY PENINSULA

DR. WILLIAM T. HORNADAY, director of the New York Zoological Park, has received the following letter, written on July 12, from the officers of the Dutch committee on the protection of birds, of which Dr. C. Kerbert, director of the Amsterdam Zoological Gardens, is chairman:

> We are pleased to be able to inform you that the committee for the advancement of a prohibition of the export of birds and parts of birds from the Dutch Colonies has received from the corresponding member of the committee, Dr. J. C. Königsberger, director of "'s Lands Plantentuin" at Buitenzorg, Java, the following information about the shooting of birds of paradise:
>
> 1. This year (and probably also in future) the shooting is limited to these species: *Paradisea minor, Seleucides nigricans* and *Ptilornis magnificus*. The export of skins of all other species is prohibited by the Dutch Colonial Government, and these skins have therefore no commercial value.
>
> 2. Shooting is *totally* prohibited in the islands of the "Radja Ampat" group (Misole, Salawatti, Batanta and Waigou), and in those of the Geelvink Bay in New Guinea, as well as in two large reservations on New Guinea, on both sides of the Geelvink Bay.
>
> By these means the protection of the rarer birds of paradise is obtained, and we have every hope that in future the shooting of all birds of paradise will be totally stopped.